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The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research, for acceptance, a thesis entitled:

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Furniture Design, Sustainable Design:

*Small Office/Home Office Furnishings – in Theory and in Practice**

By

Steven D. Bell

**Submitted as part A of a two part project: This document provides the theoretical context, method and design criteria for Part B of this project by addressing the issue and future possibilities of sustainable design. Part B of this project is a practical demonstration of sustainable design through the creation of an integrated Sustainable Designed Office System that may be viewed in the Fine Arts Building between December 4 and December 20, 2002.*

December 9, 2002

This work is dedicated to my family,
Culley, Salix, Linnea and Violet.

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This thesis is a result of the efforts and inspiration of many people and it is important to me that they are thanked.

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Abstract

The purpose of this thesis, both in its conceptual and practical forms, is to research and develop a furniture system designed for the small office/home office (SOHO) within an integrated and redefined context of sustainable design. This project adopts a multi-level approach that focuses on the development of a set of working guidelines that both reflect and are drawn from the social, environmental and economic influences that pertain to the act of design. More specifically, this project draws from, integrates and extends foundational concepts that relate to our understanding and manufacture of SOHO furniture. The resulting criteria are then used, in a conceptual model, to exemplify my belief that if we are to address questions of sustainable design and if sustainable design is to become a working reality that is part of our common manufacture and consumer practice, it must first be functionally effective. The marriage between effective functionality and sustainable design is then demonstrated by way of my furniture prototypes that were created with direct reference to the theories and concepts that are explained in this proposal.

The written report to follow begins with an over-view of the many current approaches to design for ecology (DfE), design for sustainability (DfS), eco-design, and green design within the context of industrial design. From these many, and often contradictory, overlapping and disparate approaches comes the approach that is developed and adopted for this. The project on display, designed and built in accordance with the theoretical model proposed, will be available for viewing in the Fine Arts Building, University of Alberta, from the 4th of December 2002 to the 20th of December 2002.

Project Introduction

Furniture design and fabrication within the context of sustainable design and research provides us with an opportunity to have a positive impact on the environment without the need to address often-rigid consumer habits. The impetus for such study is the increasing concern for ecologically sensitive practice in the world of industry. Since the 1960's there has been much written about the effects that consumer culture has on the world's ecosystems. Concerns about industry and consumption, however, have been a part of public discourse since the Industrial Revolution. For example, William Morris, Henry David Thoreau (*Walden*), R. Buckminster Fuller, Rachel Carson (*Silent Spring*), and Paul Hawken (*The Ecology of Commerce – a Declaration of Sustainability*) mark a progression of pivotal thinkers and philosophers who have stressed the often-tenuous relationship that human beings have with the living planet.

As this ongoing critical discussion continues to influence our perspective on the problems created by consumption, we become increasingly aware of the growing body of evidence that the present lifestyles of humankind in general and of the wealthiest ten percent in particular now challenges the very finger hold that all living systems maintain on the earth (Denison 13). It is these highly consumptive few, consumers of 80% of the world's resources, who must make a paradigm shift in their current consumer thinking. This notwithstanding, the potentially positive role that might be played by the industrial designer must be stressed since the industrial designer is often the creative force behind the production of many of the world's consumer goods. Moreover, the designer can play a key role in the development of "radical improvements" (Datschefski 8) in how products perform from the standpoint of their environmental impact. It is

by seeing the world, not as a place of dysfunction but rather, as a place of potential for improvements in the fields of design and manufacture that has most directly influenced the direction of this project. The "inertial scenario" (Manzini *Sustainability and Scenario Building,* 8) described by Ezio Manzini[1], Professor of Industrial Design and Director of CIRIS (the Interdepartmental Centre for Research on Innovation for Sustainability), is a scenario whereby those who do not care to acknowledge their personal responsibility and impact on the environment, instead remain reliant on the advent of a "miracle technology" to solve all problems. This is an example of dysfunctional thinking. Nevertheless, it would be advantageous to consider that notions of dysfunction can be viewed as profoundly fruitful and positive sources of inspiration and improvement rather than as merely provocative targets for circular critique. What is needed, therefore, is a clear working definition of "sustainability" that adopts the perspective of "non-dysfunctional" potentiality.

The term "sustainable" as it relates to design and development has been employed for more than 20 years in a multiplicity of ways using various definitions. The definition developed in 1987 by the World Commission on Environment and Development (WCED) is particularly helpful in creating a context for this project both on the level of theory and on a practical level. According to the WCED, sustainable development is "development which meets the needs of the present without compromising the ability of future generations to meet their own needs" (Elkington 1). McDonough and Braungart use much more direct and persuasive rhetoric, when they say; "design with your children's children's health and well being in mind" (14). The variations on the term "sustainable" have, each in their own way, been developed in an effort to more

[1] The work of Ezio Manzini has played a pivitol role in this research and has been a springboard for the developments in this project.

accurately deliver the essence of a particular developmental or design perspective. Design for the environment (DfE), eco-friendly design, and green design are only a few of the many terms used to describe what designers and members of responsible societies would consider as normal ethical design practice.

With an understanding based on the WCED and McDonough and Braungart, it is my intention to refocus our understanding of the term sustainable design with reference to effective design and to propose, both theoretically and practically, the creation of designed objects that can responsibly meet our needs today and tomorrow while at the same time maintaining my personal and professional commitment to the world's living systems.

Through the discussion of a conceptual model of a SOHO in the later half of this document, I will discuss the design and production concerns of furniture components that could exist within what I have called "effective sustainability." The SOHO will be especially appropriate not only because of the increasing ubiquity of the home office but because of its potential for creating a forum that is intended to encourage discussions regarding the future possibilities of sustainable design.

In addition, my overall thesis stems from the fact that there is an increasing body of evidence that indicates that objects within the near environment are responsible for a negative impact on our health and safety. An example is found with the health hazards related to "sick building syndrome". This involves chemical by-products of building material such as volatile organic compounds (VOCs) that circulate through a buildings heating and cooling systems. There is also a shift in the collective thinking towards activities such as smoking in public spaces that has lead to the public demand for changes in legislation to address health hazards. In general, the public

has become more aware, concerned and educated about the origins and content of the products they purchase and use. There is, in many areas, consumer demand for safer and more ecologically friendly products that also reflect ethical commercial practices. Coffee (and now tea), which have been labeled with the "Fair Trade"[2] logo, capitalize on this marketing demand and, from the consumer's perspective, justifies a higher price. Consumer demand lead Ikea to pay a huge economic cost estimated to be between 6$ million and $7 million (USD) in Denmark and Germany in 1992 as a direct result of their failure to react to market concerns about formaldehyde content in their best selling BILLY bookshelf line (Natrass and Altomare 52). It is, therefore, reasonable to predict that public interest in the area of product design, content and manufacturing practice will continue to drive market conditions and influence and affect the manufacture, production and design behind our consumer culture in profound and far reaching ways.

The concept of sustainable design is not beyond the realm of public concern or general necessity. Sustainability without an equal emphasis on a product's effectiveness –or that, beyond pure aesthetics, which makes the product attractive to the consumer –represents only half of the picture. As responsible designers we should thus turn our creative eye towards what I have called "effective sustainability" which would not only have a very positive impact on the consumer market by providing people with carefully designed manufactured goods that are desirably effective but, by extension and intent, would have a similarly positive impact on the worlds living systems through sustainable desire; and subsequently, levels of consumption.

[2] "Fair Trade" is a labeling system used by coffee and tea producers that endorses a product that embodies a higher level of ethical practice in harvesting and production.

Theory

Introduction

If we are to solve the problems that plague us, our thinking must evolve beyond the level we were using when we created those problems in the first place.

(Albert Einstein)

In his characteristically simple yet profound way, Albert Einstein suggested that our problem solving techniques must evolve beyond the mind-set that first created the problem. Much has been written on eco-design, green design, design for the environment (DfE), and sustainable design that has added new perspectives to the ongoing discourse. The perspectives mentioned above, however, are not always clear in their general definition or specific use of them. In order to make sense of this lack of clarity, what follows is a brief description of how these approaches use the term sustainability and why this must be readdressed.

Sustainable Design

Sustainable design must do the following: a) it must clearly address the needs as outlined in the call for design, b) it must ensure that the notion of time as it relates to the longevity of use is addressed in a manner that is appropriate to the defined need and, c) sustainable design methodology must be responsible to the external environment that is affected by the implementation, manufacture and use of the designed and built artifact. Sustainable design, from the beginning, follows a proactive approach rather than a reactive approach that limits the need to fundamentally re-conceive a product or service in the future. In other words, design attempts to prevent future problems by taking these into consideration at the ideation stage.

In *Sustainability and Scenario Building*, Manzini outlines five key characteristics of sustainable structure that in his view, if followed by concrete steps to implementation, will realize the vision of a sustainable world (1).

1. A plurality of solutions and context must be viewed that include economic, social and environmental implications.
2. A proposal must be feasible in how it relates to existing technology and socio-economic opportunities.
3. A micro-scale approach must be taken that relates to the physical and socio-cultural space that is being directly addressed.
4. Because scenario building directly relates to a physical manifestation of change, visual expressions must be used to provide a means of visually communicating proposals.
5. Key players must participate in the creation of new design.

Like wise, McDonough and Braungart describe five guiding principles that attempt to re-orient the design process (181-186).

1. Signal your intentions and commit to a new paradigm rather than an incremental improvement of old.
2. Strive for good or restorative growth rather than only economic growth.
3. Prepare for ongoing innovation, think preemptively and acknowledge that there is no last word on the subject.
4. Recognize change as being a difficult and challenging process and prepare to adapt and innovate.
5. Exert intergenerational responsibility.

The following table (Table 1), created by Fiksel (173) shows three combined aspects of product sustainability, from a manufacturing perspective, with some examples, for illustrative purposes, of issues that are related to each heading.

Economic	**Environment**	**Societal**
Direct • Raw material costs • Labour costs • Capital costs	***Material consumption*** • Product and packaging mass • Useful product lifetime • Hazardous materials use	*Quality of life* • Breadth of product availability • Knowledge enhancement • Employee satisfaction
Potentially hidden • Recycling revenue • Product disposition cost	*Energy Consumption* • Life-cycle energy • Power use in operation	*Peace of mind* • Perceived risk • Complaints
Contingent • Employee injury costs • Customer warranty cost	*Local impacts* • Product recyclability • Impact on local streams	*Illness and disease reduction* • Illnesses avoided • Mortality reduction
Relationship • Loss of goodwill as a result of customer concerns • Business interruption as a result of stakeholder interventions	*Regional impacts* • Smog creation • Acid rain • Biodiversity reduction	*Accident and injury reduction* • Lost time injuries • Reportable releases • Number of incidents
Externalities • Ecosystem productivity loss • Resource depletion	*Global impacts* • CO_2 emissions • Ozone depletion	*Health and well-being* • Nutritional value provided • Food costs

Table 1 Product Sustainability from Fiksel 173

Eco-design

> *"Imagine a world of industry that made children the standard for safety" (William McDonough and Michael Braungart)*

Thus begins William McDonough and Michael Braungarts' book *Cradle to Cradle* in which they propose an approach to design that includes not only economic, but also ecological and social concerns. This contemporary evaluation of the future of design is a reaction to anachronistic philosophy of thinkers like Sir Winston Churchill who referred to manufacturing as "the arsenal of democracy" (23) that could produce a powerful, potent response to threats of war. This profoundly single minded attitude was at once successful, efficient, profitable, and linear yet largely excluded considerations beyond economics and political stability. Assumptions were made during Churchill's time with regard to the "natural-capital" which was seen as a source of endless bounty ripe for conquering. This linear, wasteful, and inherently destructive model has created a world where 90% of raw materials extracted in the United States for durable goods become waste material (McDonough and Braungart 27). McDonough and Braungart further suggest that the notion of "brute force" (32) to make nature comply with the demands of industry, created a profusion of toxic chemicals through the use of pesticides and defoliants in such things as the production of cotton for textile manufacture.

In a similar vein to Churchill's statement, current industrial practices seem to follow the path of least resistance in an effort to manufacture a product that is desirable and affordable, that meets regulations, and performs well enough to satisfy market expectations with seemingly little concern for human and ecological health. Although this shortsighted view is changing, it is still rare for industry to address a product as "product plus". In short, this refers to a product plus its

potentially harmful toxic baggage (McDonough and Braungart 42). In general, those in industry and their shareholders often fear the costs and limited economic benefits as a result of adopting a "product plus" approach. However, as evidenced by the 3M "Pollution Pays Program" this can, if fact, be quite the opposite. From 1987 to 1997, 3M saved more than $750 million (USD) through pollution-prevention programs. The World Business Council for Sustainable Development (WCED), numbering 48 industrial sponsors including Dow, Dupont and Chevron, promotes and embraces these positive benefits. They help to reinforce the assertion that to remain competitive, businesses must adopt the practice of eco-efficiency by adding more value to goods or services while at the same time using fewer resources and releasing less pollution. In the words of Björn Stigson, President of the World Business Council for Sustainable Development, "Companies that don't get it [the concept of "product plus"] will lose their competitiveness" (Roston 57).

United States based Interface Inc., under the direction of visionary Chairman and CEO, Ray Anderson, has "accepted [their] responsibility as a member of the industrial world" (Natrass and Altomare 101). A leading commercial and domestic carpet manufacturer, Interface has addressed the take-make-waste system and is turning their entire manufacturing process into a closed loop system. In short, take-make-waste refers to the practice of raw material extraction, which leads to production, which then leads to waste. Interface is attempting to reverse this by doing the following:

1. Making efforts to eliminate waste altogether.
2. Depending on renewable rather than non-renewable resources.
3. Working to eliminate all toxic emissions.

Interface is also making a fundamental shift in the way that it addresses its market by transforming itself from a supplier of carpeting product to a supplier of carpeting services through such things as its carpet-leasing program.

Some of the greatest economic and environmental savings can be realized in the examination of material and its disposal. In fact, to eliminate the concept of waste altogether means to design a product with the understanding that waste need not exist. McDonough and Braungart suggest that products are essential nutrients of either a biological (i.e. biodegradable) or technical (i.e. re-circulated for ongoing use in industry) variety.

Life cycle analysis (LCA) is one successful manner for deciding, on a case-by-case basis, a design's ability to deal with environmental issues related to energy use, material need, component needs, reusability and durability (Chiapponi 79). LCA relies on a database that allows for a comparative examination of the following phases:

1. Raw material extraction.
2. Manufacturing and material use (e.g. dematerialization).
3. Transportation and distribution.
4. Use and reuse.
5. Maintenance and durability.
6. Recycling.
7. Final disposal.

Impact for each of these phases is assessed using parameters that include energy and material consumption as well as quantity and type of air, water and ground emissions. Of particular

interest to my project is that an LCA provides information to assist in the design, not of green products but rather, it provides for the creation of environmentally sound product lifecycles.

McDonough and Braungart write that it is fundamental for eco-design to be connected to the local "effect" (121). In planetary terms, we are all downstream, however it is important to focus on the particular stretch of this "stream" that is affected by design and manufacturing choices. Essentially, honour the local event, while at the same time recognize distant effect. In other words, 'think globally, act locally". In this regard, McDonough and Braungart ask:

1. How do any chemicals affect local water and soil?
2. What is a product made from and how does its manufacturing process affect what is upstream and downstream?

Fiksel proposes the following criteria for managing sustainability in ecodesign (172):

1. Consider stakeholders needs.
2. Identify major product aspects related to the triple bottom line.
3. Establish objectives.
4. Eliminate toxic materials.
5. Reduce waste.
6. Leased product concept.
7. Create opportunities in developing countries.
8. Select indicators and metrics for commonly used performance indicators (appendix).
9. Set targets/metrics (appendix).

The most often discussed area of eco-design is the selection of materials for the object. In many ways, this is the easiest area to discuss because of readily available information that can help to define whether or not something is renewable, or toxic or otherwise damaging to the ecosystem. For example, PVC is a known carcinogen and the most widely used plastic in the world. More than 80% of all plastic products currently in existence are manufactured from PVC which, if it catches fire, produces hydrogen chloride gas and dioxin which present both acute and chronic health hazards to building occupants as well as to fire fighters and surrounding communities (Greenpeace). PVC is also non-recyclable due to its chemical make-up. In short, PVC is not only a real and present health hazard but it is a waste-creating material. Conversely, aluminum is a raw resource that, once extracted and considered a technological nutrient (McDonough and Braungart103), may be carefully recycled many times over.

Eco-design vs. sustainable design

While the above design methods paint a rather complex and confusing picture of the various environmentally aware approaches. Tischner and Charter (121) help us to understand these categories (Fig.1) in terms of their position within a network of meaning.

Fig.1 Design Methods in Context adapted from Tischner and Charter 120

In this diagram, product design occupies a central position in relation to traditional roles of designing profitable products that meet the needs of producers and users. Ecodesign, DfE, and green design are methods that are used to consider product life cycle and resource consumption resulting from product design. Product life cycle analysis is the most common strategy used by companies who wish to begin with an ethical approach to design and the environment. The successful and profitable 3M "pollution pays" program mentioned above is an example of product life cycle assessment and is often the area to realize the most immediate economic benefit.

Sustainable product development and design is a balance of metric (i.e. standard measures) based approaches mentioned above together with an approach that enhances a quality of life that

may be sustained through creative and innovative thinking on the social, economic *and* environmental level.

Prevailing models Reconsidered: Towards an Integrated Design Method

In ecodesign methodology there is often a risk in following a "less bad" approach (McDonough and Braungart 54). Reduction only slows the process and risks allowing an already destructive process to take place over a longer, less intensive period of time. Contrary to popular belief, re-use and recycling can also contribute in a hidden negative manner by causing a path of down cycling and delayed introduction of toxins. For example, despite earlier considerations, recycling aluminum, when carried out in a non-selective manner, creates weaker and less useful material that may be contaminated with paints, coatings and manganese alloys (Burall 81). In *Our Stolen Future*, author Theo Colborn asserts, "astoundingly small quantities of certain synthetic chemicals can wreak all kinds of biological havoc, particularly in those exposed in the womb" (xvi). It is with an effective approach, rather than an efficient approach that design becomes fundamentally sustainable (Heslop). " Plainly put, eco-efficiency only works to make the old, destructive system a bit less" destructive (McDonough and Braungart 75).

There are other "rebound effects" that result from embracing eco-design as a simple process of material and manufacture re-examination. It is the culture of consumption that is the primary cause for environmental ills and, therefore, eco-redesign alone will not ultimately solve this greater problem. The Ford model, Ka, for example, produces only 2% of the Nitrogen Oxide emissions of a 25-year-old car but these improvements have been greatly outpaced by the world wide massive growth in auto use and ownership (Robins and de Leeuw 51). Granted, if all the

worlds' cars were to perform in a similar manner to the Ka, emission problems would be significantly reduced. However, there is a risk of a false sense of security in this thinking. In effect and as mentioned above, it is a "less bad" approach that is not addressing fundamental macro problems. Design for the environment (DfE) or eco-design aims to integrate environmental considerations into product design through life cycle analysis (LCA) and reduced energy and resource consumption. Where this method fails and where so-called sustainable product design (SPD) thinking achieves a higher level of positive future possibilities is through the inclusion of social and ethical aspects of a product's life cycle. Tischner and Charter suggest, however, that "value-laden" (126) social and ethical issues are much more abstract and long-term in their approach and can be difficult to measure using traditional economic and developmental models. Current practice involves only managing that which is measured.

In sum, and as I have attempted to demonstrate above, a paradigm shift towards "effective sustainability" expands the designer's vision beyond the primary purpose of a product and considers the design goals and effects across a wider place and time spectrum. This spectrum includes the societal, economical and ecological systems.

In the figure below, we find the "triple bottom line"(*fig.2*), which has been proposed by scholars such as McDonough and Braungart (150), Victor Papanek (291), Ezio Manzini, (*Sustainability and Scenario Building* 1), and Ursula Tischner 121). This scheme promotes a balanced investigation of all issues in a mutually dependent relationship rather than a conventional linear design approach that considers first cost and potential profitability, then aesthetics and attractiveness, and finally performance.

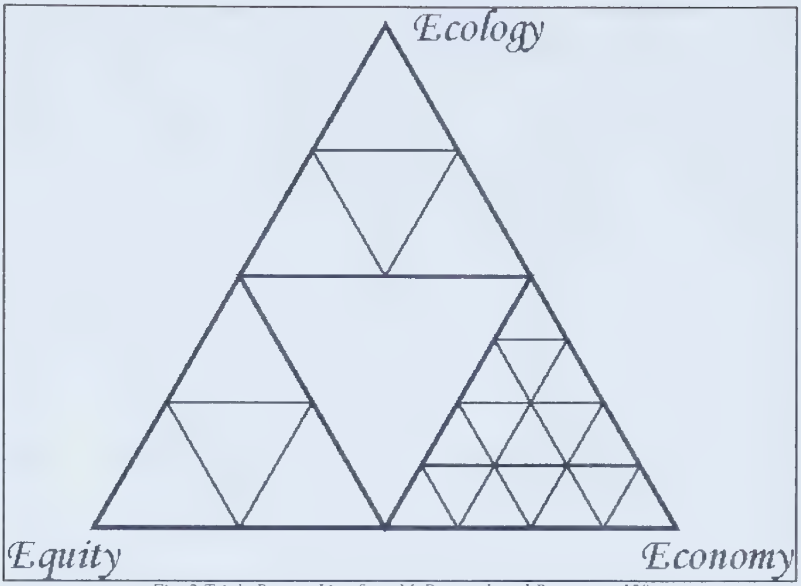

Fig. 2 Triple Bottom Line from McDonough and Braungart 150

Sales manager for international upholstery foam products company Carpenter Canada Co., Chris Murray, discussed customers' expectations of a) quality product, b) low cost, c) longevity as the bottom line. Notions of environmental stewardship are, however, considered to be good business. In his view, business must make the shift to this type of thinking not so much because of softer ethical reasons but because of powerful market drivers such as litigation (e.g. cigarette company litigation, indoor air quality) (Murray).

In conversation with Ezio Manzini in March 2002, he discussed what he felt was a human need for change (Manzini) as an influential factor in the outline of user needs. This is key to understanding and building effective sustainable scenarios. Liz Sanders proposes that co-design, a collaborative design process involving all participants, be followed in order to develop the greatest empathy for a design. (Sanders 5). It is because of this enhanced empathy that a design may have a more sustained and useful presence in a users' environment.

The intangibles of a design (Strickfaden 24) such as the embraced philosophy, symbols, and sense of value can be enhanced by making the creation and/or use of the designed object a collaborative process. To design purely for utility both ignores and puts at risk human concerns and effects. "De-humanization" can occur if the hopes, fears, dreams, and aspirations (Jordan 3) of people are not taken into account. The manner in which people interact with the artifacts with which they surround themselves is affected by this human element. "Ideo-pleasures" (Jordan 6) refers to the aesthetics and values that a product may embody. For example, "a product made from bio-degradable materials might be seen as embodying the value of environmental responsibility. This, then, would be a potential source of ideo-pleasure to those who are particularly concerned about environmental issues." (Jordan 6)

Again, it is Manzini who comes closest to describing effective sustainability in *Strategies of Localization* (6) by proposing a check list that first offers a challenge for creative thinking and follows with a recommendation for building a closer relationship with those who aim to benefit from design. His checklist is as follows:

1. Depart from business as usual; think creatively.
2. Develop a closer relationship with the customer.
3. Find new product-systems by emphasizing latent social demands and combine them into previously unseen combinations.
4. Root work in a specific social and specific context.

It is, therefore, this checklist that most informs the approach that I adopt below.

Theoretical Method Developed

As described above, in order for design to be sustainable, the design must first be the result of a proposal that effectively addresses a need. No one design can be all things to all people and so it is necessary that the design match, as closely as possible, the specific need of the user. For a balanced investigation of the three key areas of ecology, economy and society, it is necessary to follow an approach as shown by Fiskel (Table 1). This table acknowledges the variety of stakeholders, including employees, ecosystems and customers and a variety of areas such as employee health, toxic emissions and customer goodwill.

What follows is a description of a design method that results from recommendations for effective design with fundamental considerations of sustainable design and eco-design as outlined previously. Of primary importance to this method is the notion of effective design as it relates to consumer need. Design is a signal of intention (McDonough and Braungart 8) and therefore, it is fundamental to effective design that the design act is clear in its intention. In order to engage in sustainable design practice, the secondary concern to effective design is to embrace change as a cultural and social, technical and economic reality. Although it is relevant for a proposal to be feasible in how it relates to, for example, existing technology, it must also be feasible in how it addresses inevitable change. The final element of this method contains practical environmental considerations as they relate to materials management. Product development and manufacturing do not exist separate from the world's eco-system and it is relevant to acknowledge that what is a part of design is a part of all living systems.

Criteria for "Effective Sustainable" Design

The following is a list of design criteria that creates a theoretical method for "effective sustainable" design for what I propose is an effective sustainable design methodological approach.

1. **Depart from business as usual.**

In order to solve problems, thinking must evolve beyond the mind-set that created the problem. This approach involves creative thinking that aims to answer the fundamental question of the design problem. For example, a proposal that answers the fundamental need to transport people and goods in a more energy efficient way may not suggest a hyper-efficient compact car but rather may look to larger problems of urban planning. This approach may lead to a proposal for re-allocation of public transportation or address zoning laws that could enable people to live, work and shop in an urban environment that is not reliant on transportation.

2. **Consider customer needs in a specific social context or locale.**

This approach will lead to a closer relationship between the designer and the customer and therefore a greater empathy for a design, on the part of the customer and the designer. Some of the more intangible elements of a design, such as the embraced philosophy, symbols and sense of value risk being ignored if the design approach is purely utilitarian. The manner in which people interact with the artifacts with which they surround themselves is affected by this human element.

3. **Effective scenarios must accommodate the human, economic and social reality of constant change.** "Timeless" design such as children's building blocks or LEGO are simple examples that openly encourage constant change and variation in use. Design that is left open to ongoing innovation is dynamic in a way that does not assume that it is "the last word" on the subject.

4. **Consider customer's expectations.**

These expectations include a desire for low cost, quality product that embodies maximum durability and longevity in a way that is appropriate to the need. As well, thanks to the efforts of consumer advocates (e.g. Ralph Nader), customers have come to expect product safety to be an integral part of product design. For instance, a pair of latex rubber gloves to be used for a single surgical procedure must be inexpensive yet be durable enough to meet the unique needs of the surgical process while at the same time, provide a safe barrier from biohazards and infection. However, it is not necessary that they remain supple and flexible for an extended period of time beyond their single use. Conversely, a modular furniture item that may undergo several reconfigurations throughout its life must be constructed of materials that are much more durable and must be shaped in a way that allows for simplified manipulation that will limit the potential for unsafe use or handling and possible damage or injury.

5. **Human industry and the world's eco-system are mutually inclusive.**

That which is designed, created or manufactured by human beings is a part of the complete living system of the earth. This approach most closely addresses the specifics of eco-design

and is an examination of material flow. Material flow management looks at material cost and resource efficiency in the creation of the final product. In the production phase, material input, energy use, transport intensity and waste generation are key areas of interest. This includes all aspects of environmentally friendly issues that have been discussed, such as waste reduction, toxicity, re-use or disposal. As well, eco-design addresses the concept of dematerialization or material reduction. What this delivers is an equivalent, or perhaps greater, level of welfare out of fewer goods and services (Robins and de Leeuw 51). Of greatest consequence to this line of thinking is the concept of waste. Some of the greatest economic and environmental savings can be realized in the examination of the material use and its disposal. In fact, to eliminate the concept of waste altogether means to design a product with the full understanding that waste does not exist. McDonough and Braungart suggest in their book, *Cradle to Cradle*, that products are essentially elements of either a biological (i.e. biodegradable) or technical variety (e.g. re-circulated for ongoing use in industry). Materials must be labeled as to their content and subsequently can be easily disassembled and separated to facilitate re-use, recondition, and repair or returned as nutrients to the manufacturing system. As a subset of this criterion of effective sustainable design the following specific considerations must be made:

a. Eliminate toxic and hazardous material use and emissions
b. Eliminate the concept of waste.
c. Rely on renewable materials (biological or technical nutrients)
d. Acknowledge product plus its manufacturing and distribution needs.

Conclusion

Having thus reviewed the current practices and approaches that pertain to environmentally minded design and, from this, proposed my own set of "effective sustainability" design criteria, what remains is to demonstrate this in a practical manner. A theoretical model, like any set of conceptual design criteria, is only as good as the products they enable (and allow). My suggestion, throughout, has been that any future developments in industry stand to benefit from the adoption of radical improvements in how environmental stewardship is embraced. Design offers opportunities for new types of behaviours and lifestyles in keeping with a new notion of social quality and therefore begs the question, "What are some solutions that are to lead to improvements?" It must be remembered that design was and is a product of and contributor to the development model that has lead to a world in crisis. Therefore, designers must now turn their creative eye toward fruitful and positive areas for improvement.

With this in mind, I invite you to examine the SOHO integrated system designed in direct response to the questions posed throughout this paper and, more specifically, by the criteria that has resulted from my attempt to address these questions. It is my intent that the work itself, both in concept and design, will stand as a convincing conclusion to this paper.

Practice

Introduction - The SOHO Locale

Design, as has been indicated earlier, is a signal of intention (McDonough and Braungart 8) and therefore, it is fundamental to responsible design that the design act is clear in its intentions. What follows is a description of the furnishing system for the small office/home designed in accordance with the clearly defined intentions of the design criteria for "effective sustainability".

People have found it necessary to read, write, produce, and create within their home environment for a variety of personal, employment, and economic reasons. A year 2002 report on self-employment (in Canada) written by Human Resources Development Canada states that the number of self-employed Canadians has grown at a faster pace than the total number employed over the last 25 year. There are currently 2.5 million small office/home office (SOHO) workers in Canada, (10) 27.4% of these self-employed people work primarily in their own home (22). Cheryl Julich of Internet Broadcasting Systems Inc. in Minnesota describes that a natural part of a dynamic and growing high-tech company is to constantly adapt. She can "be launching 25 Web sites one minute, and the next minute…be launching 45 other sites." Her company's constant growth pattern requires a constant reconfiguration of her transitory workspace (Katz-Stone C3). As seen in this example, it is reasonable to expect that the dynamics of the SOHO scenario require rigorous analysis and intervention.

Customer needs and expectations

It has been determined that the range of possible users of SOHO furnishings system could reasonably include young couples with a median age of 32 with 90% of this group having an income of greater than $35,000 (CAN). 30% of this demographic group planned to purchase office equipment within one year (Anderson 28). This group, the Generation X, has grown up amid economic turbulence and does not take economic and household stability for granted. They are generally well educated, “technology savvy”, (28) and are “more likely to have an email address than a post office box number” (28).

In a survey conducted by Furniture/Today (Anderson 26) 17% of US households planning to purchase home office furnishing has a home-based business. To give this some perspective, in the year 2000, six million US households purchased a desk at an average price of $200 (USD). Of these, 3.8 million households had “buying plans” in the next year to purchase additional office furnishings such as file cabinets, bookcases, and seating at an average planned spending price of $150 (USD). This translates into millions of dollars in anticipated spending, even if only half of the planned spending is realized. Between 40% and 50% of these consumers are well educated, technology savvy and generally well informed about consumer group. The market demographics illustrated in the following diagram (*Table 2)* indicate not only the percentage ownership, in the household, of office equipment but also the type of equipment currently found in the home office. The growth in the use of the Internet by this group will likely lead to an increase in the number of computers and related equipment in the household. This, along with the decreasing costs of computer based equipment, will lead to an ever more increasing demand

for the hard goods such as shelves, desks and work surfaces necessary to accommodate this equipment and their related activities in the home.

Computers:	
PC compatible	62%
Apple	7%
Other	4%
Home Business	17%
Other office Equipment:	
Modem	65%
Printer	63%
CD-ROM	58%
Cellular phone	50%
Multimedia	45%
Scanner	26%
Fax Machine	21%
DVD-ROM	9%
Internet related:	
Internet access	59%
Hi-Speed connection	8%
WebTV	3%

Table 2 Computer and related equipment ownership, per US household. *Graphics by Furniture/Today, Anderson 26*

Parallel to the advancements in more affordable technology are the developments in wireless technology and miniaturization of computer equipment. The increased use of flat panel LCD monitors (as a result of their reduced cost) for example has a direct effect on the space requirements of this equipment where, traditional cathode tube monitors are both energy and space intensive in comparison to the much more compact and energy efficient LCD monitors. Wireless technology, combined with portable laptops and personal digital assistants (PDAs) such as *Palm Pilots*, as well as Internet ready cellular phones, has a dynamic affect, again, on the space requirements of a traditional SOHO. Work surface needs are reduced and equipment such as printers and scanners may be situated in a home network environment where proximity to a network hub is not limited by the length of available connection cables, but rather only by imagination.

The dream of the "paper-less" office has not transpired as anticipated and therefore it must be acknowledged that storage needs still include the accommodation of traditional methods of data retention. Books, magazines, journals, and catalogues are still a major part of the office environment despite the availability of online equivalents. Therefore, it is important that this design project include a proposal for storage and shelving needs of the SOHO.

It was determined in the design process that, due to the fluid nature of the home office, the primary issue to be addressed is the ability for furnishings to be flexible, moveable, changeable, and modular so that they may be configured and re-configured in many possible ways in order to adapt to changing needs. As outlined earlier, the SOHO environment is a dynamic space that statistically has been proven to change from time to time due to micro and macro economic changes that directly affect it.

Objects of Study and Applied Design Criteria

My design addresses the existing SOHO environment with its many variables and gives form to current and anticipated storage and workspace needs. The form taken for this design is dictated by my theoretical method which examines user requirements, the physical demands of the objects used in the workspace, and by the opportunities offered through the careful selection of materials and process that do not compromise the criteria of "effective sustainability". This project was driven by the identifiable changes in our approach to work, the need to anticipate those changes, and responsibly design for them.

The design addresses the technical storage needs of the SOHO and is configured in such a way that it is adaptable to change, due to its small and modular form and, because the panels are protected from serious damage by the aluminum extrusion, the unit is more durable than if panel edges were exposed. Adaptability and mobility are achieved because of a flexible, do-it-yourself (DIY) element that allows the user to revise the layout and uses of the shelving unit at any time and with simple tools and effort.

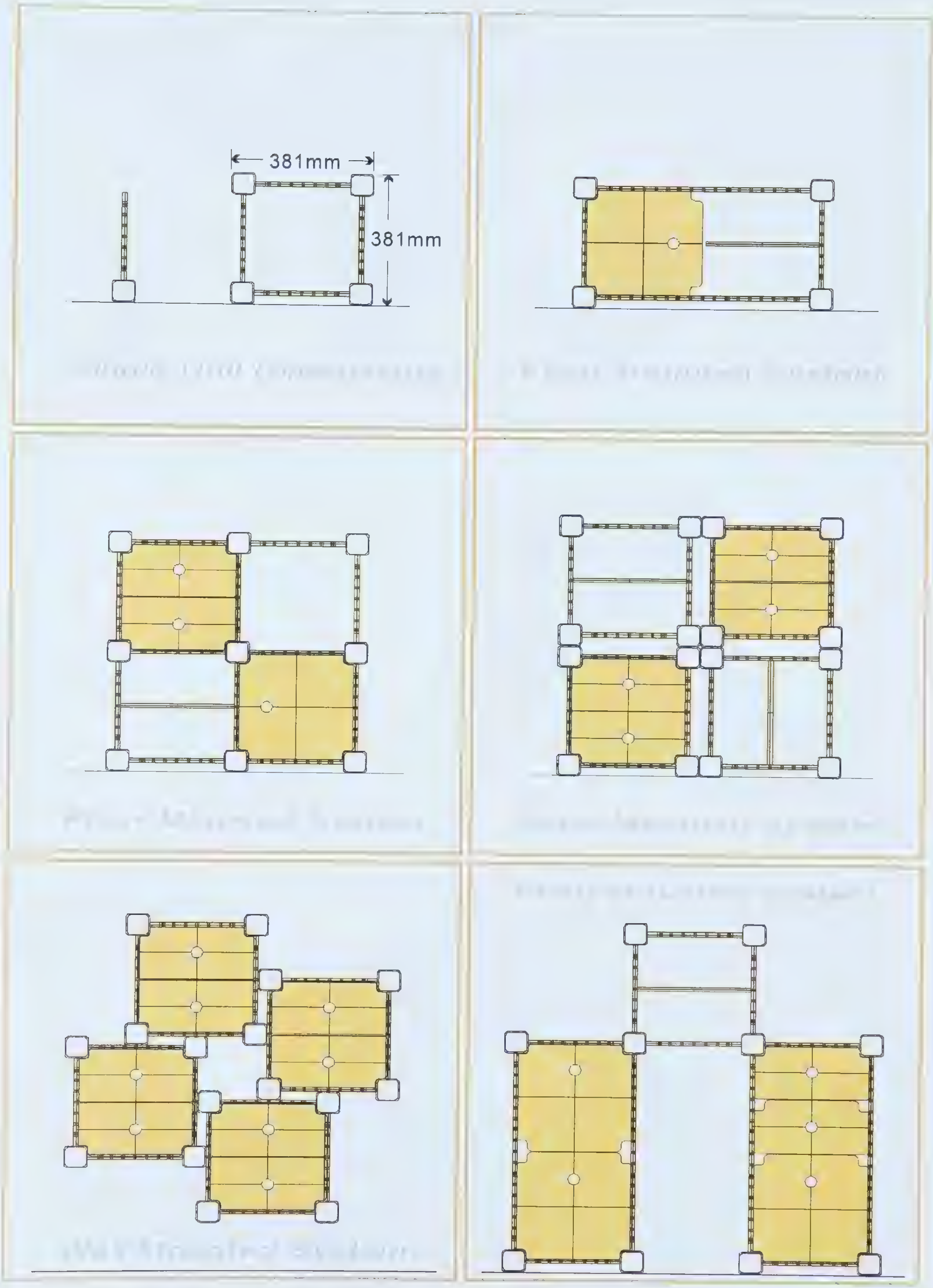

Fig. 3 Layout Variations (a), Front views

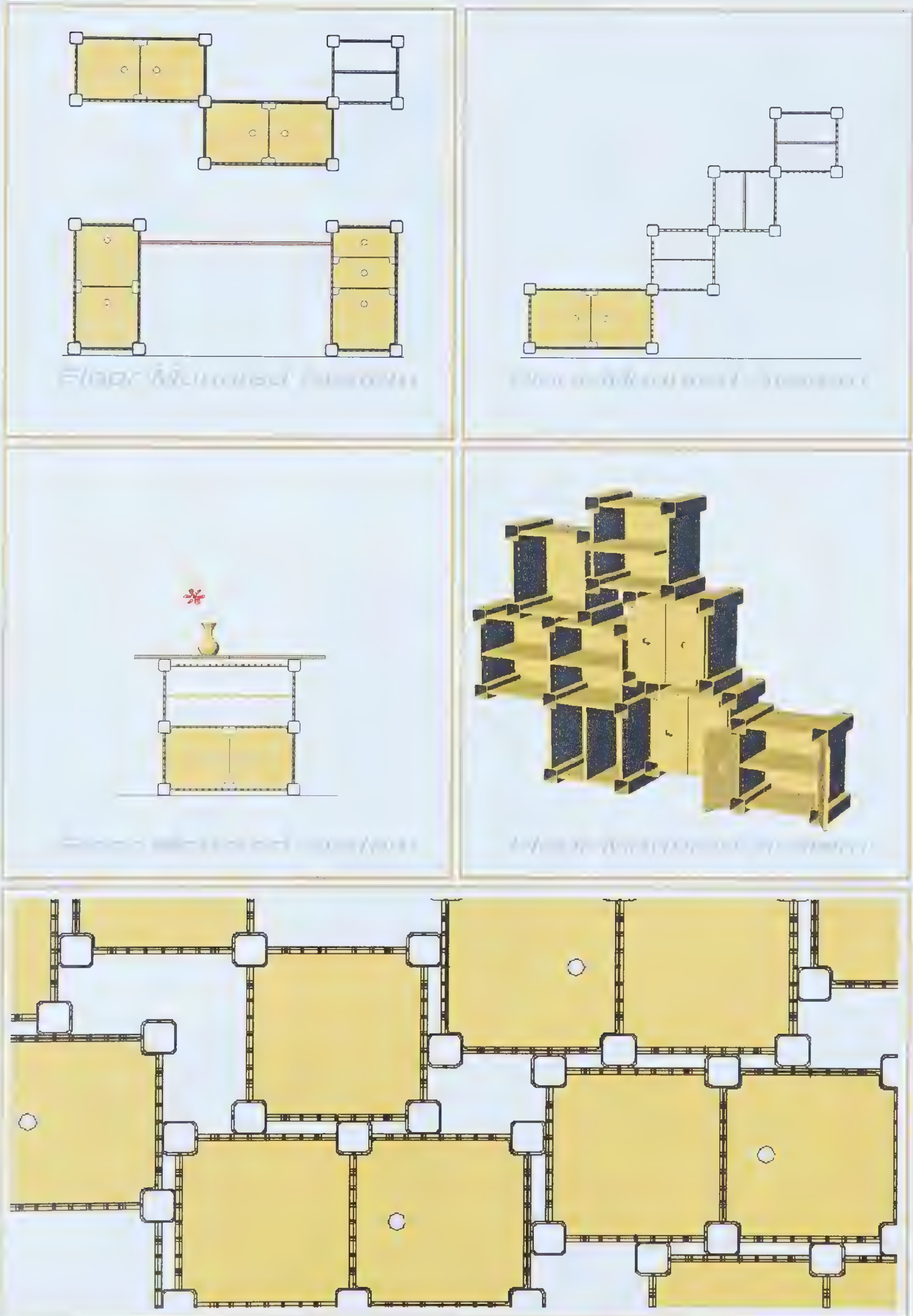

Fig. 4 Layout Variations (b). Various views

Fig. 5 Layout Variations (b), Display Case

As is seen in figures 3, 4 and 5, the design is flexible enough to accommodate a variety of storage needs, may be configured in a manner that may be personalized by the user, may have drawers, shelves, doors, or be open to adopting other third party additions. The SOHO design addresses the growing trend for do-it-yourself as well as the “enabling platform” described by Manzini in *Sustainable Solutions: New business ideas and new ideas on business* (8) where the objective of a business is to enable the delivery of a service with the environmental advantage of optimizing use while reducing quantity. The components of the design are based on a simple, consistent geometry (i.e. modular) that allows for the easy addition or subtraction of components in a continuous manner based on the immediate and future needs of the customer. Central to the SOHO design are the limited components (this design uses two variations of case dimensions based on a consistent 32mm geometry) as well as a small number of hardware pieces (i.e. bolts) necessary to connect the panels (fig.6). One configuration of extruded aluminum tubing is used and is drilled in a way that makes it universally adaptable to the panels.

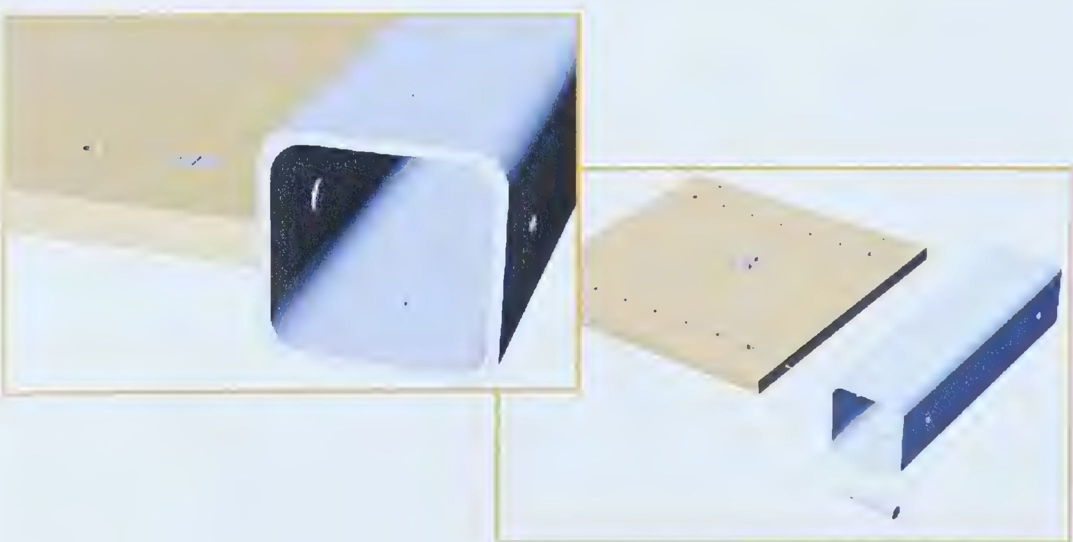

Fig. 6 Connection Details - illustrating ready-to- assemble (RTA) hardware

Proportions, as seen in the prototype, may be varied in scale, providing that the dimensions are changed relative to 32 mm geometry (i.e. The individual panel height, width, and depth may be increased or decreased by 32mm in order to arrive at case dimensions that could provide alternative storage volume and work surface area). The 32mm system is not a new development but rather, has been in use for more than 30 years by German companies such as Hettich International and Blum who use this system as a basis for the manufacture of cabinetry components.

Lightweight materials that are sensitive to environmental and toxicity issues are used in this design. The panel elements (PureKör™ wheat board), a by-product from the agricultural industry, are manufactured at significant energy savings (McLeod) as compared to conventional composite board methods using a hammer mill process rather than a shredding mill process necessary for wood fibre. Rather than using urea formaldehyde glues (UF)[3] for particle bonding, polyester resin (polymethylene polyphenylisocyanate resin - PMDI) is used and is glue that becomes inert after curing and has emissions far below the strict E1 European low formaldehyde (LF) standard. (UF is a recognized carcinogen and it is the elimination of this hazardous off gassing that is primarily driving the sales of PMDI based panels). In conversation with Wayne Wasylciw, Alberta Research Council, he stated that strawboard panels are cured in a sealed, nitrogen-rich environment that prevents the escape of gases while the panel cures and stabilizes. The panel material will biodegrade at the end of its useful life; however, it is possible instead to utilize the used material, its off-cuts and sawdust as raw material for new panels (McLeod). The use of material waste as a technical nutrient for manufacturing new panel material is more common in Europe where, for example in Italy, the demand for construction and demolition

waste exceeds its availability (McLeod). PureKör, the panel material used in the design prototypes is manufactured in Kamsack, Saskatchewan, in a location close to rail transportation (a transportation method significantly more energy efficient than trucking). The material is 15-20% lighter than similar wood based particleboard, as a result of a reduction in the necessary amount of bonding resins (4% of volume vs. 10% of volume for urea formaldehyde based panels), therefore reducing transportation and materials handling costs both for production and product shipping. The ecological and financial savings, in this area alone, are substantial if one examines the many stages that material must be transported from the raw manufacturing plant on to the furniture manufacturer and then to the customer (who themselves will likely move these goods around many times). PureKör product literature claims that their strawboard panel material exceeds ANSI A208.1 M3 (American National Standards Institute) standards for particleboard. This standard covers particleboards that are primarily from cellulosic materials. This standard covers physical and mechanical property requirements such as screw-holding capacity, hardness, rupture and elasticity, and maximum formaldehyde emissions for different grades of particleboard (see Appendix). Therefore, it is reasonable to expect that this material will comply with ANSI standards and perform in a fashion consistent with conventional particleboard used for furniture manufacture.

The aluminum extrusion and steel hardware are continuously recyclable or, because of its durability, continuously reusable as technical nutrients. Manufacturing recycled aluminum extrusion uses only 5 percent of the energy that is required for the extraction of raw bauxite for virgin aluminum production and in addition, requires only about 10 percent of the capital

[3] Urea formaldehyde is the adhesive notorious for "off-gassing" and was the glue in the IKEA *Billy* shelves that the German and Danish public took issue with in the 1992.

equipment compared with primary aluminum manufacturing. A third of the total US aluminum needs are now supplied using recycled aluminum (The Aluminum Association).

Rubber "bumpers" are friction fit into the ends of the aluminum tubing for the purpose of protecting the user from potential injury caused by inadvertently bumping into the hard ends of the tubing. Not only does this provide injury protection but it also adds an element of colour and playful variability to the monochromatic nature of the aluminum and strawboard. Traditional row crops, such as corn and soybeans, already are being used to obtain products, such as lipids and oils, for use in manufacturing rubber and plastics (Alternative Energy Institute). Therefore, the possibility to produce these rubber bumpers from biodegradable natural rubber material exists. (The material used in the prototype furniture is petroleum based, polyurethane rubber.)

Careful considerations regarding the manufacturing of the designed objects will allow for the reduction and even elimination of waste material. The panel system has been designed to rely on parallel lines and dimensions that limit wasted materials (commonly called "off-cuts") that would result from non-linear cuts such as circles or sharp curves.

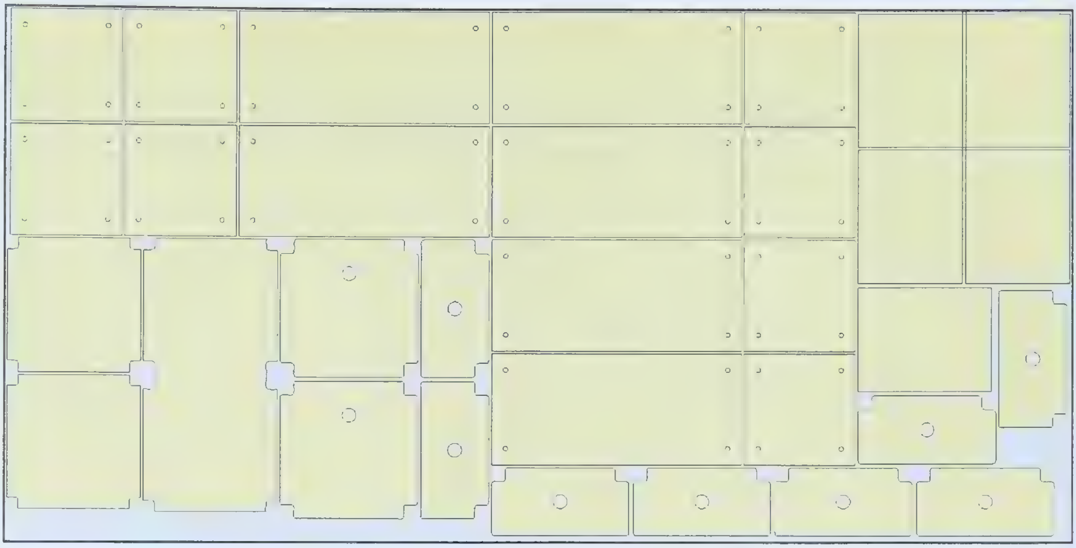

Fig. 7 Material Usage - 90 percent raw material usage for a 4' by 8' panel in this pattern layout.

Close to 90 percent of the raw material (fig.7) is used for manufacture and off cuts and sawdust may be collected and returned to the panel supplier for remanufacture.

The business solution element of this design would allow for its use in a service platform where the customer, rather than purchasing office-shelving products, could purchase office-shelving services. This not only places the ownership and reuse/disposal/repair/etc. in the hands of a stakeholder who is most interested in solid-quality durable design but also allows for the continuous re-design or reconfiguration of the elements to be used for the provision of this particular service. The service provider could supply components, on a for-lease basis, and offer upgrades or downgrades as the needs of the customer shift. As well, the service provider could continuously adopt new improvements on the design based on ongoing dialogue with their customer.

Conclusion of Practical Demonstration

This project has looked at a niche market, the small office/home office, as a means to develop the case in point. This niche was chosen because it also embodies many positive environmental, ethical and economic issues. These positive attributes range from greater job satisfaction, reduced energy consumption through the elimination of commuting to the workplace, and the improved vibrancy of communities, which would otherwise be virtual ghost towns during the workday.

Project Summary

Recommendations for further development

The notion of sustainable development and design is a topic, as has been made evident in the research, that goes far beyond the narrow scope of defining certain types of materials and their individual effect on the environment from which they are extracted. Sustainable practice of any sort embodies a manner of thinking that goes beyond the traditional approach to environmental management, which looks at pollution, toxicity, and resource extraction. It looks instead to a proactive approach to living that addresses the radical changes necessary to adjust contemporary consumer culture. Changes need to occur at the consumption level where the unsustainable demand for product must shift towards a pattern that more closely matches the clearly defined needs and wants of the consumer. Industrial designers have traditionally taken on the role of the maker of the *objects* that will fulfill the needs of the consumer and of the manufacturer and now must contribute to a future in which the consumer and the object may continue to co-exist without negative consequence. There are no easy solutions, however there are many positive paths to pursue.

This project has some limitations that must be noted, primarily because of the huge potential that this type of work offers. Therefore, it is my approach to look at these as areas of potential future development.

The practice of material selection, using life cycle analysis (LCA), is a science of metrics that relies on a vast number of variables. An in-depth LCA was beyond the scope of this project. Although the guidelines for LCA were generally followed, it was the intention of this project to

focus more on the design decisions made that would result in an effective product, while at the same time trying to adhere to ethical material selection. This is a limitation of the research as it stands and therefore is an area for further investigation.

The shift from the development of product to the development of service is a major current paradigm shift in the market place. The United Nations Environment Programme Division of Technology Industry and Economics (UNEP DTIE) is an international promoter of this shift and seeks to inspire stakeholders by exposing and developing business opportunities in this area. This is an area of positive future exploration. In this project I have proposed the development of a particular group of objects that carefully addresses the current and future needs of the consumer. Further to this project would be a deeper exploration of the business opportunities available to this product group (i.e. furnishings) by examining the desired utility to lead to the development of a mix of products *and* services that fulfill the same demand.

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- Ambient concentrations of hazardous by-products in various media
- Estimated annual population incidence of adverse effects in humans or biota
- Reduction in natural stocks of scarce resources

Economic impact

- Average life-cycle cost incurred by the manufacturer
- Purchase and operating cost incurred by the customer
- Cost savings associated with design improvements

Social impact

- Reduced accident potential
- Production worker quality of life
- Increased nutritional value

Appendix 2

Examples of Sustainability Performance Indicators (SPIs) (from Fiksel 176)

Objectives	**SPIs**	**Metrics**	**Targets**
Reduce or eliminate waste	Total waste and emissions	• Weight (e.g. kg) per year • Weight (e.g. kg) /product unit	• Reduce by 30% annually
Develop 'green' products	Recyclability of obsolete product	• Percentage recovered and recycled	• Achieve 95% recycling
Reduce life-cycle cost	Costs at each life-cycle stage	• Cost per year • Cost per product	• Reduce to $7500 per unit
Conserve energy	Energy usage over life-cycle	• Energy to produce one unit • Power use	• Reduce by 10% annually • Reduce below 30W
Conserve natural resources	Recycled content in products	• Percentage by weight of product materials that is recycled	• Recycle at least 30% • Achieve 30% recycled plastics

PANEL SOURCE INTERNATIONAL

"Formaldehyde-Here's Why We Should Be Coı

Formaldehyde is a human carcinogen and potential reproductive hazard. Off-gase and released by manufacturing facilities and combustion sources, formaldehyde is in both indoor and outdoor air.

Hazards:
Acute (Short-Term) Health Effects:

- Primary acute effects from formaldehyde exposure are eye, nose and throa problems.
- When inhaled, formaldehyde causes coughing, wheezing, chest pains, anc formaldehyde can cause fluid build-up in the lungs and even death.

Chronic (Long-Term) Health Effects:

- Formaldehyde is a human carcinogen. In the U.S. EPA classifies it as a Gr International Agency for Research on Cancer (IRAC) classifies it as a grou identified increased incidences of lung and nasopharyngeal cancer.
- Formaldehyde exposure is a potential reproductive hazard associated with menstrual disorders and pregnancy problems.

Exposure Routes:
Worker Health:
Facilities using formaldehyde must minimize worker exposure.

- Use formaldehyde in closed systems. If a closed production system is infea use local exhaust ventilation.
- Take precautions to avoid formaldehyde contact. If formaldehyde contacts seek medical attentions.
- A combustible liquid and explosion hazard, any formaldehyde solution shoı point.

Public Health:
A widely used chemical, especially in building products, and a byproduct of combu ubiquitous in urban areas and buildings at low levels.

- The highest levels of formaldehyde detected in air have been in indoor air. construction products, including particleboard and MDF, unreacted formalc Smoking is another source of formaldehyde exposure.
- Manufacturing facilities and combustion sources are a major source of forn Automobiles, power plants, incinerators, and refineries create formaldehyd combustion.
- Formaldehyde is also formed when sunlight breaks down ozone as well as

Source: The Massachusetts Toxic Use Reduction Institute. University of Massachı

Parkland Panel Products

A Div. of Parkland Strawboard (1998) Inc.

Material Safety Data Sheet

Section 1

Material Identification
Trade Name: Parkland Panel Products
Synonyms: Straw board, Fiberboard, Agrifibre Panel, Particle Board
Description: **A panel manufactured from Agri-Fibre & Resin**
Manufacturer: Parkland Panel Products
Box 1437, Kamsack, SK. S0A 1S0

Section 2

Ingredients
Agri-Fibre: Agri-Fibre produced by grinding wheat, barley or oat
Resin: Isocyanate
Product ID: **NPU 547099**
Common Name: Polymethylene Polyphenylisocyanate
Synonyms: **Polymeric MDI, PMDI**

Section 3

Physical Data
Physical State: Solid
Density Range: **608-960 kg/m3 (38-60 lb/cu.ft)**
Appearance: Pale Yellow Panel
Boiling and Melting: **N/A**
Specific Gravity: <1
pH: **N/A**
Volatiles: N/A
Vapor: **N/A**

Section 4

Fire & Explosion Data
Flash Point: **N/A**
Flammability Classification: Class “C”
Auto Ignition: Approx. 300 Degrees Celsius
Conditions of flammability: **Open Flame**
Fire Hazard: **Dust presents an explosion hazard when in contact with an ignition source**.
Means of extinction: Water, foam, carbon dioxide, dry chemical
Fire Prevention: **Avoid dust buildup**

Section 5

Reactivity Data
Stability: Very Stable
Incompatibility: Not Applicable
Decomposition: Not Applicable

Section 6

Health Effects
Routes of entry: **Skin contact, eyes and inhalation**
Symptoms-Exposure: Not Applicable
Exposure Limits: **Not Applicable**
Note: Inhalation of product dust may be hazardous.
Referred to in Section 2

Section 7

Preventative Measures
Ventilation: **Provide necessary ventilation when handling dust, raw material and resin**.
Protective Equipment: Wear dust mask when handling dust.

Section 8

First Aid Measures
Inhalation: Remove to fresh air
Eyes: **Flush eyes and under eyelids with plenty of cool water until dust particles are Flushed away. Consult physician if irritation persists.**
Skin: If sawdust irritates the skin, wash with soap and water. Remove clothing and launder before reuse.

Section 9

Preparation of MSDS
Preparation: **January 30, 2002**
Grant Lovering, Parkland Panel Products

ANSI A208.1-1999
Approved February 8, 1999

American National Standard

Particleboard

COMPOSITE PANEL ASSOCIATION
18928 Premiere Court, Gaithersburg, MD 20879
Tel (301) 670-0604, Fax (301) 840-1252
Web www.pbmdf.com

American National Standard

Approval of an American Standard requires verification by the American National Standards Institute (ANSI) that the requirements for due process, consensus, and other criteria for approval have been met by the standard's developer.

Consensus is established when, in the judgement of the ANSI Board of Standards Review, substantial agreement has been reached by directly and materially affected interests. Substantial agreement means much more than a simple majority, but not necessarily unanimity. Consensus requires that all views and objections be considered, and that a concerted effort be made toward their resolution.

The use of American National Standards is completely voluntary; their existence does not in any respect preclude anyone, whether they have approved the standards or not, from manufacturing, marketing, purchasing, or using products, processes, or procedures not conforming to the standards.

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CAUTION NOTICE: This American National Standard may be revised or withdrawn at any time. The procedures of the American National Standards Institute require that action be taken periodically to reaffirm, revise, or withdraw this standard. Purchasers of American National Standards may receive current information on all standards by calling or writing the American National Standards Institute.

Abstract

This Standard sets forth requirements and test methods for dimensional tolerances, physical and mechanical properties and formaldehyde emissions for particleboard. Methods of identifying products conforming to the Standard are specified. Property requirements are described in metric and inch-pound units.

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Composite Panel Association
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Printed in the United States of America

Contents

Foreword (This foreword is not part of American National Standard A208.1-1999.)

The first standard for particleboard—Commercial Standard CS236—was developed by the U.S. Department of Commerce in 1961. This standard covered particleboard for interior applications. The Department published a revised Standard, CS236-66, in 1966.

The American National Standard for Mat-Formed Wood Particleboard, sponsored by the National Particleboard Association, was published as ANSI A208.1-1979. It was reaffirmed in 1986 as ANSI A208.1-1979(R1986). It was revised in 1987 as ANSI A208.1-1987, in 1989 as ANSI A208.1-1989 and in 1993 as ANSI A208.1-1993. In 1997 the National Particleboard Association and the Canadian Particleboard Association consolidated into the Composite Panel Association.

There are four annexes to this 1999 Standard. Annex A is normative and is part of this Standard; Annexes B, C, and D are informative and are not part of this Standard.

Consensus for this Standard was achieved by use of the ANSI Canvass Method. The following organizations, recognized as having an interest in particleboard standards, were contacted prior to the approval of this Standard. Inclusion in this list does not necessarily imply that the organization concurred with the proposed Standard as submitted to ANSI.

American Furniture Manufacturers Assn.
APA – The Engineered Wood Assn.
Architectural Woodwork Institute
Boise Cascade Corporation
Broyhill Furniture Industries, Inc.
Bush Industries, Inc.
Business and Institutional Furniture Manufacturers Assn.
Canadian Home Builders Assn.
CanPar Industries
Collins Products LLC
Florida Plywoods, Inc.
Forintek Canada Corporation
General Services Administration/FSS
Georgia-Pacific Corporation
G-P Flakeboard Limited
Hambro Forest Products, Inc.
Hardwood Plywood and Veneer Assn.
International Conference of Building Officials
International Paper Corporation
Isobord Enterprises, Inc.
Kimball International
Kitchen Cabinet Manufacturers Assn.
Laminating Materials Assn.
Louisiana-Pacific Corporation
MacMillan Bloedel Limited
Manufactured Housing Institute
Merillat Industries, Inc.
Michigan State University
National Association of Home Builders
National Council of the Paper Industry for Air and Stream Improvement
National Research Council of Canada
National Wood Window and Door Assn.
Natural Fibre Board
North American Wholesale Lumber Assn.
North Carolina State University
Northern Engineered Wood Products, Inc.
Oregon State University
Panolam Industries
Potlatch Corporation
Proboard Limited
PSI / Pittsburgh Testing Laboratory
Rodman Industries
Roseburg Forest Products Company
Sauder Woodworking, Inc.
SierraPine Ltd.
Smurfit Newsprint Corporation
States Industries, Inc.
Tafisa Canada and Company, Ltd.
TECO/PFS
Temple
Timber Products Company
Triwood, Inc.
Uniboard Canada, Inc.
Union Camp Corporation
University of California
University of Laval
University of Maine
USDA Forest Products Laboratory
U.S. Consumer Product Safety Commission
U.S. Department of Housing and Urban Development
Washington State University
Webb Furniture Enterprises
Weyerhaeuser Company
Willamette Industries, Inc.
Wilsonart International
Woodwork Institute of California

American National Standard for Particleboard

1 Purpose and scope

1.1 Purpose

The purpose of this Standard is to establish a nationally recognized voluntary consensus standard for particleboard which provides a common basis for understanding throughout the particleboard industry and among and between those specifying and using industry products.

1.2 Scope

1.2.1 General

This Standard covers particleboards which are made primarily from cellulosic materials (usually wood). This Standard includes definitions, dimensional tolerances, physical and mechanical property requirements, and maximum formaldehyde emissions for different grades of particleboard. Also included are test methods, inspection practices, and methods of identification. The mechanical property requirements are not engineering design values.

1.2.2 Suitability for certification

This Standard was revised with reference to ISO Guide 7-1994 and is suitable for certification purposes.

2 Definitions

2.1 **Additive:** Any material added during the particleboard manufacturing process, other than the cellulosic material and a bonding system, which enhances the particleboard's dimensional stability, fire retardance, resistance to fungi and insects, or imparts other desired properties into the particleboard.

2.2 **Bonding System:** Any system used to bind particles of cellulosic material together to form particleboard.

2.3 **Specified Thickness:** Thickness specified either by the manufacturer or by the purchaser.

2.4 **Panel:** A substantial, flat, rectangular piece of particleboard.

2.5 **Panel Average Thickness:** Average of the eight measurements taken 25.4 mm (1.0 inch) in from the edge at each panel corner and at the mid-length of each panel edge.

2.6 **Panel Average Thickness from Specified:** The difference between the panel average thickness and the specified thickness.

2.7 **Particleboard:** A generic term for a composite panel primarily composed of cellulosic materials (usually wood), generally in the form of discrete pieces or particles, as distinguished from fibers, bonded together with a bonding system, and which may contain additives.

2.8 **Particles:** Discrete, small pieces of cellulosic material (usually wood).

2.9 **Variance from Panel Average Thickness:** The difference between the panel average thickness and the individual thickness measurement that varies most from that average.

3 Requirements

3.1 General

Particleboard represented as conforming to any grade in this Standard shall meet, at the time of shipment from the manufacturer, the requirements specified for that grade when tested in accordance with the provisions of this section.

Panels represented as conforming to any grade in this Standard which, after shipment from the manufacturer, have been subjected to varying conditions of environment, storage, handling, or manufacture, may not continue to conform to the Standard when subsequently tested.

3.2 Dimensional tolerances

3.2.1 **Width and length.** The trimmed width and length of particleboard panels shall conform to the applicable dimensional tolerance requirements specified in Tables A and B. Width and length shall be determined in accordance

with Section 7 of the American Society for Testing and Materials (ASTM) Standard D 1037-96a, "Standard Test Methods for Evaluating the Properties of Wood-Base Fiber and Particle Panel Materials."

3.2.2 Thickness. Thickness of panels shall conform to the applicable tolerances specified in Tables A and B. Thickness shall be measured to the nearest 0.025 mm (0.001 inch).

3.2.3 Squareness. The two diagonal measurements of a trimmed panel shall not deviate more than 3 mm per meter (0.036 inch per foot) of panel width when trimmed to finished length and width.

3.2.4 Edge Straightness. Trimmed edges of panels 600 mm (2 feet) wide or wider shall not deviate more than 1 mm per 1.5 meters (0.016 inch per 2 feet) of panel length or width. Edge straightness shall be determined by measuring to the nearest 0.5 mm (0.020 inch) the maximum deviation from a straight line extending from corner to corner on the same trimmed panel edge.

3.3 Physical and mechanical properties

Particleboard shall conform to the applicable physical and mechanical property requirements in Tables A and B. These requirements represent 5 panel averages. However, for the properties in Subsections 3.3.3 and 3.3.4, no single panel average shall be more than 20% above the requirements shown for that grade. For the properties in Subsections 3.3.5 to 3.3.11, no single panel average shall be more than 20% below the requirements shown for that grade.

3.3.1 Moisture content. The average moisture content at the time of shipment from the manufacturer for all grades except "D" grades in Table B shall not exceed 10 percent (based on the oven dry weight of the board) except as otherwise maybe agreed upon by the manufacturer and purchaser. For "D" grades average moisture content shall not exceed 9 percent or be less than 6 percent. The moisture content shall be determined in accordance with Sections 9, 119, and 120.1 of ASTM D 1037-96a. Three specimens shall be cut from different representative locations in the panel and their test results averaged.

3.3.2 Density tolerance. The average density of any particleboard panel shall not be more than 10 percent below the nominal density as specified by the manufacturer. The average panel density shall be determined from the six modulus of elasticity specimens (see Subsection 3.3.7) in accordance with Sections 9, 119, and 120.2 of ASTM D 1037-96a.

3.3.3 Linear expansion. The linear expansion between 50 and 80 percent relative humidity-shall be determined in accordance with Sections 107 through 110 and footnotes 37 through 39 of ASTM D 1037-96a. One specimen shall be cut parallel to the length of each panel to be tested, and one shall be cut perpendicular to the length of the same panel. The results of the two tests shall be averaged to determine the linear expansion for each panel.

3.3.4 Thickness swell. This section applies to the grades listed in Table B. The particleboard thickness swell shall be determined in accordance with Sections 100 through 106 of ASTM D 1037-96a for 24-hour submersion. For grade PBU one specimen shall be cut from each panel. For "D" grades two specimens shall be cut from each panel and the test results averaged to determine the thickness swell for each panel.

3.3.5 Durability of exterior glue bonding system. The average modulus of rupture after accelerated aging, when tested in accordance with Sections 111 through 117 of ASTM D 1037-96a, shall not be less than 50 percent of the modulus of rupture listed in the Table for a particular grade. The modulus of rupture shall be calculated based upon the thickness before the bonding system durability test.

3.3.6 Internal bond. The internal bond (IB) shall be determined in accordance with Sections 28 through 32 of ASTM D 1037-96a. Three specimens shall be cut from each panel to be tested and their test results averaged to determine the IB for one panel.

3.3.7 Modulus of rupture and modulus of elasticity. The values for modulus of rupture (MOR) and modulus of elasticity (MOE) shall be determined in accordance with Sections 12, 14 through 17, 20.1, and 20.3 of ASTM D 1037-96a. Alternatively, the following 2 approaches are acceptable: (1) It is not necessary to obtain a full force-deflection curve as specified in 17.1; only two force values (and corresponding deflections) within the elastic range need to be recorded, and

(2) in 20.3, P1 shall be the difference between the two recorded forces and Y1 shall be the difference between the two corresponding recorded deflections. Six specimens shall be cut from each panel to be tested. Three specimens shall be cut parallel to the length of the panel and three specimens shall be cut perpendicular to the length of the same panel. The results of the six tests shall be averaged to determine the MOR and MOE of one panel.

3.3.8 Hardness. The hardness shall be determined in accordance with Sections 68 through 73 of ASTM D 1037-96a. Two specimens shall be cut from each panel and the test results averaged to determine the hardness for each panel.

3.3.9 Face screw-holding capacity. The face screw-holding capacity shall be determined in accordance with Sections 61 through 67 and notes 25 through 27 of ASTM D 1037-96a, except that: (1) Sections 62.2 and 64 shall not apply. (2) If the panel is less than 19 mm (3/4 inch) thick, the specimen shall be made up of 2 thicknesses bonded together with an adhesive. Panels less than 10 mm (3/8 inch) thick shall not be tested, and (3) Lead holes shall be predrilled a minimum of 13 mm (0.5 inch) deep, using a bit 3.2 mm (0.125 inch) in diameter. Four tests shall be made on each panel to be tested. The results of the four tests shall be averaged to determine the face screw-holding capacity of one panel.

3.3.10 Edge screw-holding capacity. The average edge screw-holding capacity shall be determined in accordance with Sections 61 through 67 and notes 25 through 27 of ASTM D 1037-96a, except that: (1) Sections 62.1 and 64 shall not apply. (2) Panels less than 16 mm (5/8 inch) thick shall not be tested, and (3) Lead holes shall be predrilled a minimum of 13 mm (0.5 inch) deep, using a bit 3.2 mm (0.125 inch) in diameter. Four tests shall be made on each panel to be tested. The results of the four tests shall be averaged to determine the edge screw-holding capacity of one panel.

3.3.11 Concentrated loading

3.3.11.1 Requirement. This Subsection applies only to the "D" grades specified in Table B. The particleboard shall (a) support a 2670 N (600 pound) force and (b) not deflect more than 3.2 mm (0.125 inch), relative to the supports at an applied force of 890 N (200 pounds).

3.3.11.2 Test specimens. The test specimens shall be 406 mm (16 inches) square by the thickness of the material. If Manufactured Home Decking is to be used with spans greater than 406 mm (16 inches) on center, the specimen size shall be increased so that the concentrated loading test will be conducted using the actual spans. One specimen shall be cut from each panel to be tested.

3.3.11.3 Test apparatus. A frame shall be used to support the test specimen on all four sides. The distance between supports shall be 38.1 mm (1.5 inch) less than the rated span. A method of rigidly fixing the specimen to the frame shall be provided. The test force shall be applied in the center of the specimen using the end of a loading bar having a 25.4 mm (1.0 inch) diameter with the end edges rounded to a radius of 1.25 mm (0.05 inch). A means of applying a force of up to 2670 N (600 pounds) to the bar shall be provided. The applied force shall be measurable within one percent.

A dial gauge for measuring specimen deflection relative to the supporting shall be mounted across the frame members immediately adjacent to the loading bar.

3.3.11.4 Test procedure. With the specimen firmly fixed in place, set the deflection gauge at zero. Apply a force of 890 N (200 pounds). Maintain this force until the deflection stabilizes and then record the deflection. Gradually increase the force until a 2670 N (600 pound) force is reached or failure occurs.

3.4 Formaldehyde provisions

Formaldehyde emissions from particleboard bonded with a resin system containing formaldehyde, other than an exclusively phenol formaldehyde resin system, shall be tested in accordance with "Standard Test Method for Determining Formaldehyde Concentrations in Air and Emission Rates from Wood Products Under Defined Test Conditions Using a Large Chamber" (ASTM E 1333-96). Emissions shall not exceed the maximum levels for each grade specified in Tables A or B. The loading ratios for grades H, M, D, and PBU shall be 0.425 m^2/m^3 (0.13 ft^2/ft^3) and for grade LD shall be 0.13 m^2/m^3 (0.04 ft^2/ft^3).

4 Identification

4.1 Explanation of grades

The particleboard grades in this Standard are identified by a letter(s) designation, followed by a hyphen and a digit or letter. Special performance characteristics are identified by the use of a letter(s), number, or term located immediately following the grade designation.

The first letter(s) designations have the following meanings:

H High density (generally above 800 kg/m^3 (50 lb/ft^3))

M Medium density (generally between 640-800 kg/m^3 (40-50 lb/ft^3))

LD Low density (generally less than 640 kg/m^3 (40 lb/ft^3))

D Manufactured Home Decking

PBU Underlayment

The second digit or letter designation indicates the grade identification within a particular density or product description. For instance, "M-2" indicates medium density particleboard, Grade 2.

The optional third designation indicates that the particleboard has a special characteristic. For instance, "M-3-Exterior Glue" indicates medium density particleboard, Grade 3, made with exterior glue to comply with the durability requirements in Subsection 3.3.5.

4.2 Information to be provided

All particleboard which is represented as conforming to this American National Standard shall be identified with the following information:

a) Manufacturer's name or trademark and mill identification

b) "ANSI A208.1-1998"

c) Grade

d) Lot number or date of production

e) For D grade products only, the words "MANUFACTURED HOME DECKING" and the certified load span if greater than 406 mm (16 inches) for compliance with Subsection 3.3.11 Concentrated loading "CONCENTRATED LOAD TESTED AT (INSERT SPAN IN INCHES)"

f) For PBU grade products only, the word "UNDERLAYMENT".

g) For products complying with Subsection 3.3.5 only, the words "EXTERIOR GLUE".

4.3 Methods of identification

For grades in Table A, the information required by Section 4.2 shall be provided either by (a) stamping it on each panel or (b) providing a written statement thereof in a unit label, invoice or other document associated with each panel. For grades in Table B the information required by Section 4.2 shall be stamped on each panel.

Table A
Requirements for Grades of Particleboard [1,2]

Grade[3]	Dimensional Tolerances			Physical and Mechanical Properties[4]							
		Thickness Tolerance[5]						Screw-holding			
	Length & Width mm (inch)	Panel Average from Specified mm (inch)	Variance from Panel Average mm (inch)	Modulus of Rupture N/mm² (psi)	Modulus of Elasticity N/mm² (psi)	Internal Bond N/mm² (psi)	Hardness N (pounds)	Face N (pounds)	Edge N (pounds)	Linear Expansion max. avg. percent	Formaldehyde Maximum Emissions ppm
H-1	±2.0 (0.080)	±0.200 (0.008)	±0.100 (0.004)	16.5 (2393)	2400 (348100)	0.90 (130)	2225 (500)	1800 (405)	1325 (298)	NS[6]	0.30
H-2	±2.0 (0.080)	±0.200 (0.008)	±0.100 (0.004)	20.5 (2973)	2400 (348100)	0.90 (130)	4450 (1000)	1900 (427)	1550 (348)	NS	0.30
H-3	±2.0 (0.080)	±0.200 (0.008)	±0.100 (0.004)	23.5 (3408)	2750 (398900)	1.00 (145)	6675 (1500)	2000 (450)	1550 (348)	NS	0.30
M-1	±2.0 (0.080)	±0.250 (0.010)	±0.125 (0.005)	11.0 (1595)	1725 (250200)	0.40 (58)	2225 (500)	NS	NS	0.35	0.30
M-S	±2.0 (0.080)	±0.250 (0.010)	±0.125 (0.005)	12.5 (1813)	1900 (275600)	0.40 (58)	2225 (500)	900 (202)	800 (180)	0.35	0.30
M-2	±2.0 (0.080)	±0.200 (0.008)	±0.100 (0.004)	14.5 (2103)	2250 (326300)	0.45 (65)	2225 (500)	1000 (225)	900 (202)	0.35	0.30
M-3	±2.0 (0.080)	±0.200 (0.008)	±0.100 (0.004)	16.5 (2393)	2750 (398900)	0.55 (80)	2225 (500)	1100 (247)	1000 (225)	0.35	0.30
LD-1	±2.0 (0.080)	+0.125 (0.005) -0.375 (0.015)	±0.125 (0.005)	3.0 (435)	550 (79800)	0.10 (15)	NS	400 (90)	NS	0.35	0.30
LD-2	±2.0 (0.080)	+0.125 (0.005) -0.375 (0.015)	±0.125 (0.005)	5.0 (725)	1025 (148700)	0.15 (22)	NS	550 (124)	NS	0.35	0.30

l) Particleboard bonded with a resin system containing formaldehyde, other than an exclusively phenol formaldehyde resin system, is subject to the formaldehyde emission conformance requirements.

2) Grades listed in this table shall also comply with the appropriate requirements listed in Section 3 of this Standard. Panels designated as "Exterior Glue" must maintain 50% MOR after ASTM D 1037 accelerated aging (Subsection 3.3.5).

3) Refer to Annex B for general use and grade information.

4) Physical and mechanical property values represent a five panel average.

5) Thickness tolerance values are only for sanded panels. Unsanded panels shall be in accordance with any thickness tolerances specified by agreement between the manufacturer and the purchaser.

6) NS - Not Specified

Table B
Requirements for Grades of Particleboard Flooring Products [1,2]

Grade[3]	Dimensional Tolerances			Physical and Mechanical Properties[4]							
		Thickness Tolerance[5]									
	Length & Width Tolerance mm (inch)	Panel Average from Specified mm (inch)	Variance from Panel Average mm (inch)	Modulus of Rupture N/mm^2 (psi)	Modulus of Elasticity N/mm^2 (psi)	Internal Bond N/mm^2 (psi)	Hardness N (pounds)	Concentrated[6] Loading N (pounds)	Thickness Swell max. avg. mm (inch) percent	Linear Expansion max. avg. percent	Formaldehyde Maximum Emissions ppm
PBU	+0 (0) -4.0 (0.160)	±0.375 (0.015)	±0.250 (0.010)	11.0 (1595)	1725 (250200)	0.40 (58)	2225 (500)	NS[7]	1.6 (0.063) NS	0.35	0.20
D-2	±2.0 (0.080)	±0.375 (0.015)	±0.250 (0.010)	16.5 (2393)	2750 (398900)	0.55 (80)	2225 (500)	2670 (600)	NS 8	0.30	0.20
D-3	±2.0 (0.080)	±0.375 (0.015)	±0.250 (0.010)	19.5 (2828)	3100 (449600)	0.55 (80)	2225 (500)	2670 (600)	NS 8	0.30	0.20

1). Particleboard bonded with a resin system containing formaldehyde, other than an exclusively phenol formaldehyde resin system, is subject to the formaldehyde emission conformance requirements.

2) Grades listed in this table shall also comply with the appropriate requirements listed in Section 3 of this Standard. Panels designated as "Exterior Glue" must maintain 50% MOR after ASTM D 1037 accelerated aging (Subsection 3.3.5).

3) Refer to Annex B for general use and grade information.

4) Physical and mechanical property values represent a five panel average.

5) Thickness tolerance values are only for sanded panels. Unsanded panels shall be in accordance with any thickness tolerances specified by agreement between the manufacturer and the purchaser.

6) In addition to supporting 2670 Newtons, “D” grades shall not deflect more than 3.2 mm (0.125 inch), relative to the supports at an applied force of 890 N (200 pounds). See Subsection 3.3.11 “Concentrated loading.”

7) NS - Not Specified

Annex A
(Normative)

References

The materials identified below are referenced in this American National Standard and are part of the Standard.

ASTM D 1037-96a, Standard Test Methods for Evaluating the Properties of Wood Based Fiber and Particle Panel Materials

ASTM E 1333-96, Standard Test Method for Determining Formaldehyde Concentrations in Air and Emission Rates from Wood Products Under Defined Test Conditions Using a Large Chamber

ISO Guide 7-1994, Guidelines for drafting of standards suitable for use for conformity assessment

Annex B
(Informative)

General use and grades

Use	Grade	Table
Commercial	M-1, M-S	A
Industrial	M-2, M-3	A
High density industrial	H-1, H-2, H-3	A
Door core	LD-1, LD-2	A
Interior Stair Tread[1]	M-3	A
Exterior construction	M-1-Exterior glue, M-S-Exterior glue, M-2-Exterior glue, M-3-Exterior glue	A
Exterior industrial	M-1-Exterior glue, M-S-Exterior glue, M-2-Exterior glue, M-3-Exterior glue	A
High density exterior industrial	H-1-Exterior glue, H-2-Exterior glue, H-3-Exterior glue	A
Underlayment	PBU	B
Manufactured Home Decking	D-2, D-3	B

1) Product requirements for particleboard interior stair tread are specified in the U.S. Department of Housing and Urban Development (HUD), Use of Materials Bulletin No. 70b that is available from the Composite Panel Association or HUD.

Annex C
(Informative)

Metric values

The 1975 Metric Conversion Act, as amended by the Omnibus Trade and Competitiveness Act of 1988, states that metric (SI) is the preferred system of measurement in the U.S. All Federal agencies must conduct their business in metric by September 1992, to the extent feasible.

The testing and property requirements in this Standard were converted during the 1993 Standard revision from the English inch-pounds to metric, in most instances using a "rationalized" conversion where the new metric values are rounded to an appropriate degree of precision[1]. Inch-pound units are shown in parentheses after the metric value and are generally precise mathematical conversions from the metric.

The conversion factors for the units found in this Standard are as follows:

Dimensions	
1 inch	= 0.0254 meter (m)
1 inch	= 25.4 millimeters (mm)
1 m	= 39.370 inch
Mass	
1 gram (g)	= 0.0022046 pound (lb)
1 lb	= 453.5924 g
Force	
1 newton (N)	= 101.9716 g
1 N	= 0.2248029 lb
1 g	= 0.0098067 N
1 lb	= 4.448222 N
Force/area	
1 pascal (Pa)	= 1 N/m^2
1 kilopascal (kPa)	= 0.001 N/mm^2
1 megapascal (MPa)	= 1 N/mm^2
1 N/mm^2	= 145.037 pounds per square inch (psi)
1 psi	= 0.0068948 N/mm^2

[1] ASTM E 29-93a, Standard Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications

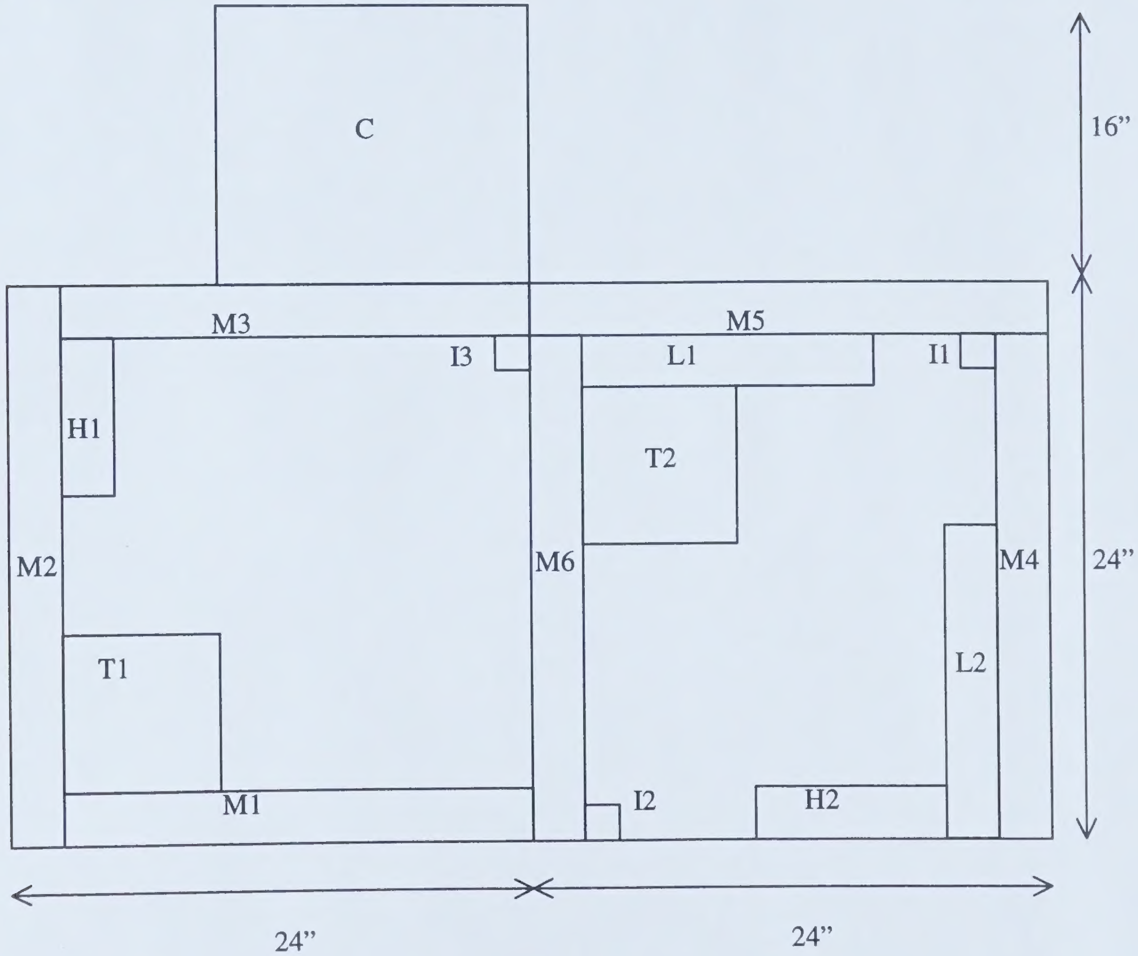
Metric Values

Conversions for:		Rounded to:
force (Newtons)	less than 100 N	nearest 1 N
	greater than 100 N	nearest 10 N
stress (N/mm^2)	less than 2 N/mm^2	nearest 0.01 N/mm^2
	between 2 and 30 N/mm^2	nearest 0.1 N/mm^2
	greater than 30 N/mm^2	nearest 1 N/mm^2
dimensions	less than 50 mm	nearest 0.025 mm
	between 50 and 500 mm	nearest 0.1 mm
	greater than 500 mm	nearest 1 mm

Annex D
(Informative)

Sample cut-up pattern [1]

H - Hardness
I - Internal Bond
L - Linear Expansion
M - Modulus of Rupture/Elasticity[2,3,4]
T - Thickness Swell (Required only for grades PBU, D-2 and D-3)
C - Concentrated Load (Required only for grades D-2 and D-3)



1) Refer to the appropriate ASTM D 1037-96a test procedure for information on specimen size requirements.
2) Density shall be determined from the modulus of elasticity specimens and screw-holding specimens may be cut from modulus of rupture specimens after breaking.
3) The exact dimension of MOR/MOE specimens is dependent on specimen thickness.
4) Moisture content samples may be cut from broken MOR specimens.